

**PATENT
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HEADPHONE AMPLIFIER

Inventors: Richard Stinnett
912 Mangrove Circle
Corona,
California 92881
U.S. Citizen

Albert Ray Trussell
419 N. Larchmont Blvd., #86
Los Angeles,
California 90004
U.S. Citizen

Russell D. Bellin
1404 N. Catalina Street
Los Angeles,
California 90027
U.S. Citizen

Attorneys:

Jon E. Hokanson
Thomas M. Small
Brian F. Drazich
Small Larkin, LLP
10940 Wilshire Boulevard
Eighteenth Floor
Los Angeles, California 90024
Tel. (310) 209-4400
Fax (310) 209-4450

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Background of the Invention

A. Field of the Invention

The present invention relates to a portable stereo headphone system including headphones, stereo audio source and an amplifier external to the headphones and audio source.

B. Description of the Prior Art

External, portable stereo headphone amplifiers are known. However, known portable stereo headphone amplifiers are relatively large, bulky, and have essentially all interior components mounted on a single side of a printed circuit board internal to a housing, extraneous controls and control circuitry and essentially no effective separation between the circuitry and a battery source of power.

Objects and Summary of the Invention

It is an object of the invention to provide a compact, external portable stereo headphone amplifier system having improved signal clarity.

It is a further object of the present invention to provide a compact, external portable stereo headphone amplifier having improved protection of its circuitry from damage caused by battery leakage.

It is a further object of the present invention to provide a compact, external portable stereo headphone amplifier having structural components arranged so as to provide for improved convenience and usefulness as a portable amplifier.

It is a further object of the present invention to provide a compact, external portable stereo headphone amplifier having improved separation between its battery source of power and its circuitry so as to minimize impact damage caused by momentum of the battery, and to maximize protection from damage caused by dirt particles or other debris from the battery compartment into the region of the housing which the circuitry is positioned.

Brief Description of the Drawings

Figure 1 is an external, prospective view of a preferred embodiment of the portable stereo headphone amplifier system of the present invention.

Figure 2 is a front, external, prospective view of the amplifier unit case or housing of the figure 1 embodiment.

Figure 3 is a view of the top surface of a preferred amplifier circuit board.

Figure 4 is a view of the bottom surface of the figure 3 amplifier circuit board.

Figure 5 is a rear, oblique view of the figure 2 amplifier unit case, with the battery compartment cover removed.

Figure 6 is a block diagram showing the relationship between figure 6A and figure 6B.

Figure 6A and 6B jointly show a base circuit diagram of a preferred circuit of the stereo headphone amplifier according to the present invention.

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Description of Preferred Embodiments

Preferred embodiments of the present invention will be described with reference to the accompanying drawings.

Figure 1 illustrates the present stereo headphone amplifier system, including compact case or housing **90**, the input of which amplifier is connected by conventional audio cable **74** to a stereo audio source **66** such as a conventional cassette tape or compact disc player. The output of the stereo amplifier is connected by conventional stereo headphone cable **76** to conventional headphones or earphones **68**.

Figure 2 is an external oblique view of the stereo amplifier case **90** showing its configuration and controls. In a preferred embodiment case **90** has overall external dimensions of approximately 2.4 inches by 4.2 inches by 0.9 inches. With respect to Figure 2 **J2** and **J3** show conventional 3 mm input and output audio jacks, respectively. Switch **S1** is the power supply on/off switch. Volume control is provided by means of volume control wheel **86**, which is rotatably connected to potentiometers **T1A** and **T1B** as shown in Figure **6A** and Figure **6B**. Advantageously jacks **J2** and **J3** are mounted on the same surface of case **90**, that surface being the external surface on which all other controls are mounted, to facilitate use as a portable amplifier unit. By having the jacks mounted on

the same surface, rather than on different surfaces, the unit more conveniently fits within a carrying case, a pocket, or other location and so the cords extending from and attached to the jacks, will be concentrated on one surface.

Figure 3 illustrates circuit board **80** and depicts representative components installed on the top surface **82** of circuit board **80**. For clarity, not all of the components contained in the amplifier circuits and power supply circuits are illustrated. In accordance with one preferred feature of the present invention, the larger components of the amplifier circuits and power supply circuits are installed on the top surface **82** of circuit board **80**. Such components include audio signal input jack **J2**, audio signal output jack **J3**, power supply on/off switch **S1** together with electrical conductors **88** and **89** which connect to a conventional battery power source. Also contained on top surface **82** is volume control wheel **86** which is mechanically rotatably connected with potentiometers **T1A** and **T1B**. Additional, relatively large components include **C41** Capacitor **81**, **C11** Capacitor **83**, **C15** Capacitor **85**, **C22** Capacitor **87**, **C21** Capacitor **89**, **C14** Capacitor **91**, **L1** Inductor **93**, and **C8** Capacitor **95**.

Figure 4 illustrates the bottom surface **84** of circuit board **80** and upon which the smaller components of the stereo amplifier circuits and power supply circuits are installed as is shown by a stylized unnumbered representation of circuit components.

As is shown in Figures 3 and 4, the installation of circuit components on both the top surface **82** and bottom surface **84** of circuit board **80** advantageously permit the amplifier unit to be contained in a relatively small volume. This placement of components enables the use of compact case **90**, which, in turn, provides for improved convenience and

portability of the external amplifier of the present invention. A further advantage flowing from the installation of selected circuit components on opposite surfaces of the circuit board 80 provides for reduction in electrical interference between components, and thus, improves the clarity of the signals processed through the circuit. In a preferred embodiment, the amplifier circuitry for the two stereo audio channels are located on opposite sides of the circuit board 80.

Figure 5 illustrates an external view of compact case 90 from a perspective opposite that of Figure 2. Whereas figure 2 shows a perspective from the top and front of the case 90, figure 5 shows a perspective view from the bottom, rear of the case 90 case with the battery component case cover, not shown, removed. Battery compartment 72 is preferably sealed and isolated from that portion of case 90 which houses circuit board 80. Battery compartment 72 permits changing batteries without exposure of the amplifier circuits and power supply circuits. Because the battery compartment 72 is sealed from the compartment which houses circuit board 80, the amplifier circuits and power supply circuits are protected from contamination due to battery leakage and/or other contaminants that could cause damage to the circuits if permitted to enter the compartments in which the circuits are positioned. Additionally, a separate mounting of the battery provides an increased measure of protection against damage to the circuit board when the amplifier unit is dropped, or is otherwise struck. In prior art amplifiers, the battery is attached to the printed circuit board and, in the event the amplifier is dropped or hit, the momentum associated with movement of the battery is transferred directly to the printed circuit board and its components. In comparison, when the battery is separately mounted in a separate compartment, the

momentum generated by the battery upon dropping of the unit, is not directly transferred to the circuit board and its components.

Figures 6A and 6B represent a highly stylized circuit diagram of the components of the stereo amplifier circuit 100. Reference symbols I, II and III denote regions into which the three major stereo amplifier circuit components are segregated on circuit board 80 in one preferred embodiment. It is to be understood, as previously described, that battery terminals B1, B4 are not mounted on the circuit board. Reference symbol II denotes those components mounted on the top surface 82 of circuit board 80. Reference symbols I and III denote those components mounted on the bottom surface 84 of circuit board 80.

Power Supply Circuit

Electrical power for the stereo amplifier preferably is provided by 3 volt batteries, AA size, at terminals B1 and B4 with the negative terminal B4 passing to ground. Positive battery terminal B1 is connected through double pole, double throw on/off switch S1 through 470 μ H inductor L1 to junction 500, which connects with the LX pin 6 of a conventional negative buck regulator circuit U3. In a preferred embodiment the negative buck regulator U3 is a Maxim MAX752 step-up regulator. The regulator circuit is configured so the battery terminals float and the circuit's ground reference allows the output of the regulator to be positive. Junction 500 connects with junction 501 through a zener diode D5.

V+ pin 8 of the step-up regulator U3 connects to junction 502, and thence to junction 503, which passes to ground through 47 μ F electrolytic capacitor C14. Junction

503 connects to junction 504 through 10,000 ohm ("10K") resistor R26 and thence to the shut down pin 1 of the step-up regulator U3. Terminal 504 connects to terminal 505 through 47 μ F electrolytic capacitor C15 oriented with its positive terminal toward junction 504. Junction 505 connects to 0.1 μ F capacitor C16 to the SS pin 3 of the step-up regulator U3. Junction 505 also connects to junction 506 through 0.01 μ F capacitor C17 to the VREF pin 2 of the step-up regulator U3. Junction 506 connects to junction 507 through 2200pF capacitor C18 to junction 508, which in turn connects to the CC pin 4 of the step-up regulator U3. Junction 507 connects to junction 509 and through 7.5K resistor R28 to junction 510. Junction 508 connects through junction 511 to junction 510. Junction 511 connects through 0.01 μ F capacitor C19 to junction 512. The Vout pin 7 of the step-up regulator U3 connects with junction 512 which connects with junction 513 and through 31.6K resistor R27 to junction 510. Junction 509 connects with junction 514 which connects with junction 502 through 0.1 μ F capacitor C20. Junction 514 connects with junction 515 through 470 μ F electrolytic capacitor C21 oriented with its positive terminal toward junction 515. Junction 515 connects with junctions 513 and 501. The ground pin 5 of the step-up regulator U3 passes to ground. Utilizing the preferred 3 volt input, the output of the step-up regulator U3 is approximately 6.4 volts at junction 501. As is conventional, the step-up regulator provides for a higher voltage than that provided by the battery power source, in order to enable a useful and preferred dynamic range for the amplifier of the present invention.

Junction 501 connects with the input pin 16 of conventional voltage regulator U4. In a preferred embodiment voltage regulator U4 is a Linear Technology LT 1121

micropower low drop out regulator with shut down. The regulator **U4** adjust pin **12** reference voltage is 3.75 volts referenced to ground. The adjust pin **12** is connected to junction **516** between 31.6K resistor **R29** and 60K resistor **R30**. Resistor **R30** is connected to junction **518** and thence to ground. The ground pin **14** of voltage regulator **U4** is connected to junction **518** and thence to ground. Resistor **R29** connects to junction **517** which connects to junction **518** 470 μ F electrolytic capacitor **C22** oriented with its negative terminal toward ground. The output pin **10** of regulator **U4** is connected to junction **517**. A regulated output voltage greater than 5 volts positive with reference to ground is provided at junction **517** to other circuit components as indicated in the circuit schematic, Figures 6A and 6B, by the reference character +5V. Neglecting the small contribution of the adjust pin **12** current, the **U4** output regulated voltage +5V is approximately equal to 5.7 volts.

Stereo Audio Amplifier Circuit

With reference to Figures 6A and 6B, left and right input audio signals (**L**, **R**) are applied at input phone jack **J2**. Input signal **R** is applied between conductor **J2R** and ground conductor **J2G**, and is directed along conductor **J2R** to junction point **200**. Junction **200** is connected through 100K, resistor **R12** to ground, and to 1.0 μ F capacitor **C5** and thence to junction point **201**. At junction **201** audio input signal **R** is directed to junction **403** in region **II** between the 100K resistor **R32** and the 280K resistor **R33**, and is directed to non-inverting terminal **38R** of conventional operational amplifier ("op amp") **U1C**.

Regulated voltage is supplied to op amp **U1C** through terminal **34R** in the manner described for op amp **U2A** as follows. Terminal **40R** of op amp **U1C** passes to ground. The signal **R** output of op amp **U1C** at terminal **32R** is fed back through junction **216** to inverting terminal **36R**. Junction **216** connects the signal **R** channel output of op amp **U1C** through 10K resistor **R13** to junction **215**. Junction **215** receives the signal **L** channel output of conventional op amp **U1D** through 31.6K resistor **R11**. The signal **R** channel and signal **L** channel signals converge at junction **215** where the outputs of op amps **U1C** and **U1D** are combined. As may be appreciated, some of the left signal **L** is bled into the right channel and some of the right channel signal **R** is bled into the left channel amplifier. In this fashion, both of the stereo channels receive some sound input from the opposite channel, to thereby provide for a total sound experience which is more natural, in the sense that naturally occurring sounds are heard by both ears, with the sound generated closer to one ear dominating in that ear and the same sound, while being heard in the ear farther away from the sound's origination is less intense.

Junction **215** connects the combined signal **R** channel and signal **L** channel voltages through 1.0 μ F capacitor **C6** to volume control potentiometer **T1A**, one side of which is shunted to ground. The output from potentiometer **T1A** is connected to junction **217** through 1.0 μ F capacitor **C7**.

Regulated voltage is supplied through 110K resistor **R17** to junctions **219** and **218** and through parallel 110K resistor **R16** and 1.0 μ F capacitor **C9** to ground through junction **220**. Junction **218** connects through 280K resistor **R15** to junction **217** and thence to non-inverting terminal **68** of conventional op amp **U1B**. Regulated voltage is supplied to

terminal **64** of op amp **U1B** in the manner described for terminal **24R** of op amp **U2A**.

Output terminal **62** of op amp **U1B** is connected to junction **221** which in turn is connected to the base of NPN transistor **Q1** through 100 ohm resistor **R19**. Junction **221** is connected to junction **222** through diodes **D1** and **D2** in series and thence to ground through 2.74K resistor **R21**. Junction **222** is connected to the base of PNP transistor **Q2** through 1000 ohm resistor **R20**.

Regulated voltage is supplied to the collector of transistor **Q1**. The emitter of transistor **Q1** is connected to junction **223** through 100 ohm resistor **R22**. Junction **223** connects junction **224** and thence through parallel 68.1K resistor **R18** and 130pF capacitor **C10** to junction **225**. Junction **225** connects junction **226** and thence through 7.5K resistor **R14** 10 μ F and electrolytic capacitor **C8** to ground. Electrolytic capacitor **C8** is connected with its negative terminal to ground as is conventional.

Junction **226** connects to inverting terminal **66** of op amp **U1B**. Thus, a gain control feedback network is established between the op amp output **62** through transistor **Q1** and the filter (**R18** and **C10**) to the inverting input **66** of op amp **U1B**.

The collector of PNP transistor **Q2** is connected to ground. The emitter of transistor **Q2** is connected through 10 ohm resistor **R23** to junction **227** which connects with junction **223**, thus coupling the emitters of transistors **Q1** and **Q2**. Junction **227** connects with junction **228** through 470 μ F electrolytic capacitor **C11** oriented with its positive terminal toward junction **227**. Electrolytic capacitor **C11** is selected to have a predetermined specific frequency response over the audio frequency range. Junction **228** connects to junction **429** through 10 ohm resistor **R24** and 0.1 μ F capacitor **C12** in series

and thence to ground. Junction **228** connects with output conductor **J3L** of stereo output phone jack **J3**, to output an audio signal across conductor **J3L** and ground conductor **J3G**.

Regarding region **II**, the right channel amplifier circuit, regulated voltage is supplied through 110K resistor **R31** to junction **404**, which connects with junction **403** through 280K resistor **R33** and thence to junction **405** through parallel filter network 110K resistor **R34** and 1.0 μ F capacitor **C31** to junction **406** and then to ground through junction **407**. Junction **407** connects through 560pF capacitor **C32** and 31.6K resistor **R35** in series to junction **408**. Junction **403** connects junction **408** through 100K resistor **R32**, and junction **408** connects conventional op amp **U2A** to direct signal **R** through non-inverting terminal **22R**. Regulated supply voltage is supplied to op amp **U2A** through junction **409** to terminal **24R**. Terminal **409** connects to ground through 0.1 μ F capacitor **C33**. Terminal **26R** of op amp **U2A** is connected to ground. The output of op amp **U2A** at terminal **18R** is directed to a feedback connection with inverting terminal **20R** through junction **410** and 10 ohm resistor **R36** to control the gain of op amp **U2A**. Junction **410** connects junction **411** through parallel 10K resistor **R37** and 300K resistor **R38** to junctions **412** and **413** respectively. Junction **412** passes to ground through 560pF capacitor **C34** and connects to the non-inverting terminal **48R** of conventional op amp **U2D**. Terminal **50R** of op amp **U2D** passes to ground. Regulated voltage is supplied to terminal **44R** of op amp **U2D** in the manner previously described for op amp **U2A**. The signal **R** output of op amp **U2D** at terminal **42R** is passed through junction **414** and thence through 10K resistor **R39** through junction **413** to a feedback connection at inverting terminal **46R**. Junction **414** passes to ground through 68.1K resistor **R40** and connects junction **415** through 31.6K

resistor **R41**.

Input signal **L** is applied between conductor **J2L** and ground conductor **J2G**, and is directed along conductor **J2L** to junction point **400**. Junction **400** is connected through 100K resistor **R42** to ground, and to 1.0 μ F capacitor **C35** and thence to junction point **401**. At junction **401** audio input signal **L** is directed to junction **203** in region **I** between 100K resistor **R2** and 280K resistor **R3**, and is directed to non-inverting terminal **38L** of conventional op amp **U2C**.

Regulated voltage is supplied through resistor **R1** to junction **204**, which connects with junction **203** through 280K resistor **R3** and thence to junction **205** through parallel filter network 110K resistor **R4** and 1.0 μ F **C1** to junction **206** and then to ground through junction **207**. Junction **207** connects through 560pF capacitor **C2** and 31.6K resistor **R5** in series to junction **208**. Junction **203** connects junction **208** through 100K resistor **R2**, and junction **208** connects conventional op amp **U1A** to direct signal **L** through non-inverting terminal **22L**. Regulated supply voltage is supplied to op amp **U1A** through junction **209** to terminal **24L**. Terminal **209** connects to ground through 1.0 μ F capacitor **C3**. Terminal **26L** of op amp **U1A** is connected to ground. The output of op amp **U1A** at terminal **18L** is directed to a feedback connection with inverting terminal **20L** through junction **210** and 10 ohm resistor **R6** to control the gain of op amp **U1A**. Junction **210** connects junction **211** through parallel 10K resistor **R7** and 300K resistor **R8** to junctions **212** and **213** respectively. Junction **212** passes to ground through 560pF capacitor **C4** and connects to the non-inverting terminal **48L** of op amp **U1D**. Terminal **50L** of op amp **U1D** passes to ground. Regulated voltage is supplied to terminal **44L** of op amp **U1D** in the manner

described for op amp **U2A**. The signal **L** output of op amp **U1D** at terminal **42L** is passed through junction **214** and thence through 10K resistor **R9** through junction **213** to a feedback connection at inverting terminal **46L**. Junction **214** passes to ground through 68.1K resistor **R10** and connects junction **215** through 31.6 resistor **R11**.

5 Regulated voltage is supplied to op amp **U2C** through terminal **34L** in the manner described for op amp **U2A**. Terminal **40L** of op amp **U2C** passes to ground. The signal **L** output of op amp **U2C** at terminal **32L** is fed back through junction **416** to inverting terminal **36L**. Junction **416** connects the signal **L** channel output of op amp **U2C** through 10K resistor **R43** to junction **415**. Junction **415** receives the signal **R** channel output of op amp **U2D** through 31.6K resistor **R41**. The signal **L** channel and signal **R** channel signals converge at junction **415** where the outputs of op amps **U2C** and **U2D** are combined.

10 Junction **415** connects the combined signal **L** channel and signal **R** channel voltages through 1.0 μ F capacitor **C36** to volume control potentiometer **T1B**, one side of which is shunted to ground. The output from potentiometer **T1B** is connected to junction **417** through 1.0 μ F capacitor **C37**.

15 Regulated voltage is supplied through 110K resistor **R47** to junctions **419** and **418** and through parallel 110K resistor **R46** and 1.0 μ F capacitor **C39** to ground through junction **420**. Junction **418** connects through 280K resistor **R45** to junction **417** and thence to non-inverting terminal **58** of conventional op amp **U2B**. Regulated voltage is supplied to terminal **54** of op amp **U2B** in the manner described for terminal **24R** of op amp **U2A**. Output terminal **52** of op amp **U2B** is connected to junction **421** which in turn is connected to the base of NPN transistor **Q3** through 100 ohm resistor **R49**. Junction **421** is connected

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to junction **422** through diodes **D3** and **D4** in series and thence to ground through 2.74K resistor **R51**. Junction **422** is connected to the base of PNP transistor **Q4** through 100 ohm resistor **R50**.

Regulated voltage is supplied to the collector of transistor **Q3**. The emitter of transistor **Q3** is connected to junction **423** through 10 ohm resistor **R52**. Junction **423** connects junction **424** and thence through parallel 68.1K resistor **R48** and 130pF capacitor **C40** to junction **425**. Junction **425** connects junction **426** and thence through 7.5K resistor **R44** and 10 μ F electrolytic capacitor **C38** to ground. Electrolytic capacitor **C38** is connected with its negative terminal to ground as is conventional.

Junction **426** connects to inverting terminal **56** of op amp **U2B**. Thus, a gain control feedback network is established between the op amp output **52** through transistor **Q3** and the filter (**R48** and **C40**) to the inverting input **56** of op amp **U2B**.

The collector of PNP transistor **Q4** is connected to ground. The emitter of transistor **Q4** is connected through 10 ohm resistor **R53** to junction **427** which connects with junction **423**, thus coupling the emitters of transistors **Q3** and **Q4**. Junction **427** connects with junction **428** through 470 μ F electrolytic capacitor **C41** oriented with its positive terminal toward junction **427**. Electrolytic capacitor **C41** is selected to have a predetermined specific frequency response over the audio frequency range. Junction **428** connects to junction **429** through 10 ohm resistor **R25** and 0.1 μ F capacitor **C13** in series and thence to ground. Junction **428** connects with output conductor **J3R** of stereo output phone jack **J3**, to output an audio signal across conductor **J3R** and ground conductor **J3G**.

As may be seen from above, the proportion of the left channel signal entering into

and being amplified in the right channel and, conversely, the degree to which the right input signal entering into and be amplified in the left channel is predetermined, rather than having separate controls for individual variations. As such, this predetermined crossover feature provides for a ready-to-use, simple construction tailored to the portability of the amplifier.

As also may be observed, the left channel and the right channel are identical to each other except that one is left, one is right, and a predetermined portion of the input signal from one channel is fed or bled into the opposite channel so that the output signal is a blend of the two input signals with the blended left output signal being dominated by the left input signal and the right output signal being dominated by the right input signal.

Also, as is readily apparent, all of the signals from each channel is sent over to the opposite channel but the crossover signal is amplified less in relation to the amplification of the primary signal in each channel.

As is also conventional, and may be seen in the drawings, this circuit provides for filtering before and after each amplification stage in order to minimize the amount of noise in the system. Also, the cables are conventional cables preferably about 12-36 inches in length and chosen to be compatible with a particular sound input device, such as a cassette player, or walkman type CD player, as well as compatible with particular headphones or earphones chosen for the particular uses and vision for the present invention, it is preferable that a relatively fixed, durable, wear resistant covering be provided for the cable, in that the cable preferably is not a twisted-pair type of a cable, but rather just 3 wires, including a left, right and ground wire, each with its own insulation, which in turn is

surrounded by the durable cover.

Also, as may be appreciated, the present invention is without structures to provide for a typical residential wall outlet source of power. Rather, in the present invention, only a battery power supply is envisioned.

5 It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations as they are outlined within the description above and within the claims appended hereto. While the preferred embodiments and application of the invention have been described, it is apparent to those skilled in the art that the objects and features of the present invention are only
10 limited as set forth in the claims appended hereto.